COPY FOR MR. J. ALLAN ROSS

HYDRO-ELECTRIC INQUIRY COMMISSION

ENGINEERING DATA

THE QUEENSTON-CHIPPAWA POWER DEVELOPMENT

CHAPTER "H"—CONSTRUCTION PLANT

CONCRETE AND REINFORCED CONCRETE

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS

Chapter [illegible].

[illegible]

(Concrete and Reinforced Concrete)

Walter H. [illegible].

Chapter H.

CONSTRUCTION PLANT

(Concrete and Reinforced Concrete)

Walter J. Francis.

WALTER J. FRANCIS & COMPANY.

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INDEX TO CHAPTER H.

Concrete and Reinforced Concrete Section

Subject | Page

INDEX TO CHAPTER H.

Concrete and Reinforced Concrete Section

LIST OF ILLUSTRATIONS

Concrete and Reinforced Concrete Section

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Concrete and Reinforced Concrete Section

Chapter H.

CONSTRUCTION PLANT

Walter J. Francis.

The construction plant of the Hydro-Electric Power Commission as used on the Queenston-Chippawa Power Development consisted principally of concreting plant and of earth and rock excavation plant, together with all the accessories such as transportation equipment and rock crushing machinery and conveying apparatus. The first part of this Chapter will be devoted to a description of the concreting Plant.

CONCRETE AND REINFORCED CONCRETE CONSTRUCTION

Concreting Practice.

The practice of the engineers of the Hydro-Electric Power Commission in regard to concrete construction differs from the ordinary standard practice. Many leading engineers are seriously considering the change of present standard practice to incorporate, entirely or in part, the principles now followed by the Hydro-Electric Power Commission. In standard practice it is the custom to pre-determine the amount of cement to be used in concrete, whereas by the practice of the Hydro-Electric Power Commission the strength of the concrete

is pre-determined and the amount of cement is apportioned accordingly. This has been the practice of the Commission for a number of years. The method is based in part on the water-cement-ratio-strength-relation theory of Professor D. A. Abrams, and in part on the researches of Mr. L. N. Edwards on proportioning concrete mixtures by surface area.

The cement required per batch for a normal consistency mixture may be determined from the physical analysis of the aggregates used, their weight per cubic foot and the quantity of each in the batch. The water required per batch is obtained by multiplying the amount of cement required per batch by the proper water-cement ratio. This is the maximum quantity of water per batch which can be used. The water present in the aggregate must be deducted from this maximum allowable quantity to obtain the amount of water which is to be added at the mixer in gauging. The proper deduction is determined by reference to the tests for moisture content made daily on the aggregates. If the quantities of cement and water be thus determined, the resulting mixtures will be of uniform consistency and the finished concrete will have the required compressive strength.

Normal consistency is a consistency which has been arbitrarily chosen in the laboratory, and represents approximately the driest mixture which can be placed under the best field conditions. Any other degree of plasticity may be obtained without appreciably affecting the quality of the finished concrete by increasing the cement and water content proportionately. A consistency which required 15 per cent. more cement and water than did this normal consistency has been found suitable for chuted concrete.

Water-cement ratio, as ordinarily defined, is the ratio of the volume of water to the volume of cement, but in the practice of the Hydro-Electric Power Commission it is defined as the ratio of the weight of water to the weight of cement. Using the volumetric water-cement ratio in practical proportioning gave rise to considerable confusion which has been almost entirely overcome by the use of the weight basis.

Four classes of concrete, called for convenience Classes "A", "B", "C" and "D", were in use on the work. Class "A" was specified as being of such quality as to show a minimum compressive strength of 2,500 pounds per square inch at the age of twenty-eight days when tested in accordance with the standard methods of the Commission. Classes "B", "C" and "D" were required to have minimum compressive strengths of 2,000, 1,500 and 1,000 pounds per square inch, respectively, under the same conditions. The testing methods of the Commission are the same as those of the American Society for Testing Materials.

A complete system of inspection was carried out commencing with the materials at their source of supply.

Proportions for the various classes were set by the chief field inspector, and were determined by a modification of the Edwards surface area method of proportioning as developed in the laboratories of the Commission. By this method not only were the proportions of cement and aggregate set, but also that of the water. This was accomplished by limiting the quantity of water per bag of cement for each class of aggregate. The consistency of the mixtures used was such as to flow readily, but without segregation, down a chute with

[illegible] ratio, as ordinarily defined, is the ratio of the volume of water to the volume of cement, [illegible] [illegible] it is defined as the ratio of the weight of water to the weight of cement. [illegible] the use of the weight basis.

[illegible] and [illegible], [illegible] strength of 2,500 pounds per square inch [illegible] were required to have [illegible] respectively, under the same conditions. The testing methods [illegible] are the same as those of the American Society for Testing Materials.

A complete system of [illegible] materials [illegible].

[illegible] and aggregate [illegible], but also [illegible] per bag of cement for each class of aggregate. The consistency of the mixtures [illegible]

a slope of one vertical to two and a half horizontal. Where the consistency could not be obtained with the proportions set, or where circumstances required a wetter mixture, additional cement was added until the ratio of water to cement was brought within the prescribed limits. In other cases where a drier consistency could be used, advantage was taken of the circumstances by using less cement, always maintaining the proper ratio of water and cement.

It is interesting to note, in passing, that the method of determining the proportions according to the practice of the Hydro-Electric Power Commission results in a material reduction in the quantity of cement over that which would ordinarily be estimated for concrete of equal quality. Mr. R. B. Young, the Senior Assistant Laboratory Engineer of the Commission, who directs the application of the above principles, has made an estimate which shows an actual saving of over 50,000 barrels of cement by using the principle of the Hydro-Electric Power Commission as compared with standard practice to obtain concrete of equal quality for the 410,000 cubic yards of concrete made up to the end of the year 1921. All the estimates show a very material saving in the Commission's practice.

The average amount of cement used per cubic yard of concrete in all classes has been 1.28 barrels of 350 pounds net weight. The averages for the different classes have been as follows, although in isolated cases Class "C" concrete, for example, has required as much as 1.48 barrels of cement per cubic yard, while at other times only 1.01 barrels per cubic yard have been necessary,-

actual figures as used on job

Average Amount of Cement Used per Cubic Yard of Concrete

Class	Barrels per Cubic Yard	Compressive Strength per sq. in.
"A"	1.67	Minimum of 2,500 pounds at 28 days
"B"	1.46	" 2,000 " "
"C"	1.20	" 1,500 " "
"D"	0.98	" 1,000 " "

COPY

Concrete Work.

All of the masonry in the permanent work is of concrete or reinforced concrete. The concrete has been made of Portland cement and water with an aggregate of sand and crushed rock. The principles employed by the engineers of the Hydro-Electric Power Commission have already been discussed in the opening part of this Chapter.

Concreting of the canal lining was commenced in November, 1920, and the bulk of it was completed by the middle of December, 1921. During the winter of 1920-1921 and again in the latter part of 1921, calcium chloride was used in the concrete of the canal lining to accelerate the hardening process and so enable the canal lining plants to proceed rapidly. The quantity of chloride used varied from 6 to 15 pounds per yard batch, averaging 9 pounds per batch or about 2½ per cent. by weight of the cement in the mixture. The chloride was delivered to the mixing plant in drums and dissolved in water as required. The method usually followed was to fill a barrel with water to a mark set by the

inspector. The chloride was then added until the water level rose to a second mark, steam being then admitted into the barrel to dissolve the chloride until the surface level of the mixture rose to a third mark, yielding a solution of the desired strength. Two gallons of the solution was added to each batch of concrete by discharging it into the barrel used to proportion the water. A very noticeable increase in early strength of the concrete was obtained by its use, and it was possible to strip the forms in as short a space of time as twelve hours, even in freezing weather.

Quality of Concrete.

The concrete throughout the work is of excellent quality. The alignment is good. The surface is dense and its texture is uniformly even.

Cement.

A total of 508,125 barrels of cement was used up to December 31st, 1921. It was obtained from five different mills. The greater part of the cement was "bin tested", that is it was sampled, tested and accepted before it left the mill. To make this possible, special bins were reserved at the mills for the exclusive use of the Hydro-Electric Power Commission. While these bins were being filled, samples of the cement were taken from the conveyor and sent to the Commission's laboratory at Toronto for test. Shipments were not made until the cement was shown by test to be satisfactory. It was loaded on the cars as required under the supervision of the superintendent resident at the mill. The

arrangements of the concreting plants on the work permitted the handling of cement in car lots, hence accepted cement could be used directly on receipt at the work without delay and without re-handling.

Owing to the serious cement shortage experienced in the summer of 1920, the engineers of the Commission decided to store a large quantity of cement during the winter of 1920-1921. Three large sheds were erected, one 20 feet wide and the others 35 feet, with a total length of 1,750 feet. In these sheds 112,000 barrels of cement were stored in compact piles 11 feet high. The doors of the buildings were then sealed and not re-opened until the cement was needed. This cement was stored over the winter, the storage period for part of it extending to eleven months. It is stated that no appreciable deterioration was found when the tests were made before using.

The orders for cement placed by the Hydro-Electric Power Commission during the years 1916 to 1921, inclusive, are given on the table on page H-8. This list includes all the orders for the cement used by the Commission during this period and is not confined solely to the Queenston-Chippawa Power Development as will be seen by reference to the remarks.

Sand.

The sand was obtained from several different sources. The first supply, being that used in 1917-1918, came from a pit which was acquired as part of the right-of-way. Subsequently a pit was purchased which met the needs of the work until the Spring of 1921, when it became necessary to obtain large quantities

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List of Orders for Portland Cement placed

between March 1918

Firm Receiving Order	Date of Order	Price per Barrel	
Alfred Rogers, Limited, Toronto, Ontario.	March 18, 1918.	$2.45 per barrel	......
	February 5, 1919.	$3.10 " "	......
	April 10, 1920.	$3.20 " "	......
	January 17, 1921.	$4.00 " "	......
Hanover Portland Cement Company. Toronto, Ontario.	July 29, 1920.		......
Canada Cement Company, Limited, Montreal, Quebec.	January 21, 1918.	$2.45 " "	......
		$3.15 " "	......
	December 9, 1918.	$2.80 " "	......
		$2.80 " "	......
		$3.40 " "	......
	April 21, 1920.	$3.20 " "	......
		$3.90 " "	......
		$4.15 " "	......
	December 10, 1920.	$4.00 " "	......

COPY

by the Hydro-Electric Power Commission

and March 31st, 1922.

Quantity and Remarks

..... 25,000 barrels Cement, f.o.b. St. Mary's. Freight allowed to Niagara Falls.

..... 50,000 barrels Cement, f.o.b. St. Mary's. Freight allowed to Niagara Falls.

..... 50,000 barrels Cement, f.o.b. St. Mary's. Freight allowed to Niagara Falls, High Falls or Eamey Falls.

..... 90,000 barrels Cement, f.o.b. St. Mary's. Freight allowed to Niagara Falls, Port Stanley or Windsor.
Price reduced to $3.75 per barrel on December 15th, 1921.

COPY

..... The right to purchase total output of plant on basis of 1,000 barrels per day output at cost of production plus 50¢ per barrel, $1.62 per barrel being named as the maximum cost and the Hydro-Electric Commission to deliver the necessary stone at 90¢ per ton.

..... 50,000 barrels Cement, f.o.b. Mill. Freight allowed to Niagara Falls.
..... Freight allowed to Cronyn.

..... 50,000 barrels Cement, f.o.b. Mill. Freight allowed to Niagara Falls.
..... 10,000 barrels Cement, f.o.b. Mill. Freight allowed to other points.
..... 15,000 barrels Cement, f.o.b. Mill. Freight allowed to Cronyn.

..... 125,000 barrels Cement, f.o.b. Mill. Freight allowed to Niagara Falls.
..... Freight allowed to Cronyn during navigation season.
..... Freight allowed to Cronyn out of navigation season.

..... 400,000 barrels Cement, f.o.b. Mill. Freight allowed to Niagara Falls, the
650... Company agreeing to hold reserve stock against the order.

On July 27th, 1921, the Canada Cement Company reduced the price of $4.00 per barrel to $3.75 per barrel. On May 12th, 1922, they further reduced the price to $3.40 per barrel, war tax extra.

of sand from other sources.

Approximately 235,000 cubic yards of sand were purchased. Half of this was obtained from a pit accessible to the service tracks of the work, and the balance was brought from Lake Ontario.

The pit sand was loaded by steam shovel into dump cars at the sand pit and delivered by the contractor either directly to the concreting plants or to the storage pile situated at the Forebay.

The lake sand was dredged from the sand bar at the mouth of the Niagara River by a sand-sucker having 500 cubic yards capacity, and capable of making four round trips per day from the sand bar to the disposal wharf. On the wharf, which is situated at Niagara-on-the-Lake beside the tracks of the Michigan Central Railroad, was a large storage bin into which the sand was deposited from the sand-sucker. It was taken from the bin by derricks with clam shell buckets and loaded into standard steel dump cars in which it was hauled twelve miles to the Commission's siding at Stamford. At Stamford it was taken by the Hydro-Electric Power Commission locomotives and distributed to the mixing plants or sent to the storage pile according to circumstances.

Both the pit sand and the lake sand were of limestone origin, the pit sand having an average surface area of 2,130 square feet per 100 pounds, and the lake sand a corresponding average surface area of 1,680 square feet. This is equivalent to a fineness modulus of 2.7 and 2.2 respectively. The pit sand contained fine materials passing the No. 150 sieve to the extent of 4 to 8 per cent. by weight. The lake sand contained practically no fine material. To attain the same result at the mixer plants under identical conditions, the pit sand was found to require approximately one-half of a bag of cement more for

each batch of concrete than the lake sand, due in part to the difference in gradation and in part to the difference in the character of the constituent particles of the two aggregates.

The sand was purchased at a cost of $1.50 per cubic yard, delivered, for the pit sand, and $1.65 per cubic yard, delivered, for the lake sand. The lake sand was purchased from the National Sand & Material Co. of Welland, Ontario.

Crushed Rock.

The crushed rock was a dolomitic limestone from the canal excavation, selected as required from the steam shovel output, which varied from comparatively small pieces up to those having a volume of several cubic yards. It was delivered as excavated to a 60" x 84" jaw crusher specially built to handle it. After passing through the jaw crusher where it was reduced to approximately 6 inches in size, it was carried by belt conveyors to a battery of four gyratory crushers which reduced it to approximately 2½ inches in greatest diameter, and smaller. From the gyratory crushers it passed to a screening plant where the dust was removed on a 3/8-inch "dust jacket", and the larger parts were screened out on a revolving screen 6½ feet in diameter and 30 feet long, fitted with plates having 3-inch round openings, which gave commercially 2½-inch screened crusher run. This was discharged upon a belt and taken to storage. The over-size from the screen went to a small gyratory crusher which reduced it to 1½ inches. The product of this crusher was screened and stored separately, and used where the larger sized material would be unsuitable. The

capacity of the crushing and screening plant was 3,000 cubic yards per day. This capacity was reached in operation, the output averaging nearly this figure for extended periods. The grading of the crushed rock was practically uniform between 1/4 inches and 2½ inches. It contained on an average 8 per cent. of dust and crusher screening. It was reasonably free from flat and elongated pieces.

The product of the crusher plant was not used entirely for concrete work, a condition which necessitated the consideration by the engineers of the most suitable maximum dimension for its output. The choice of 2½ inches as a maximum size was a compromise between the requirements of the concrete aggregate on the one hand and the large quantities of crushed rock which were to be used for ballast, highways, foundations and fill on the other. If only requirements of the concrete could have been considered, a smaller maximum size would have been more satisfactory, since its use would have been less severe on the concreting plant and the concrete would have been easier to handle and to place. Approximately one-third of the stone crushed up to the end of the year 1921 has been used for concreting.

Crusher Plant, Stock Piles and so forth.

The principal storage for the aggregate was located at the Forebay in conjunction with the crusher plant, the general arrangement of which may be clearly seen in the aeroplane photograph included herewith as page H-12. This photograph has been marked with reference figures for convenient use. The figure 1

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To face page H-12

No. H-1

Photograph showing

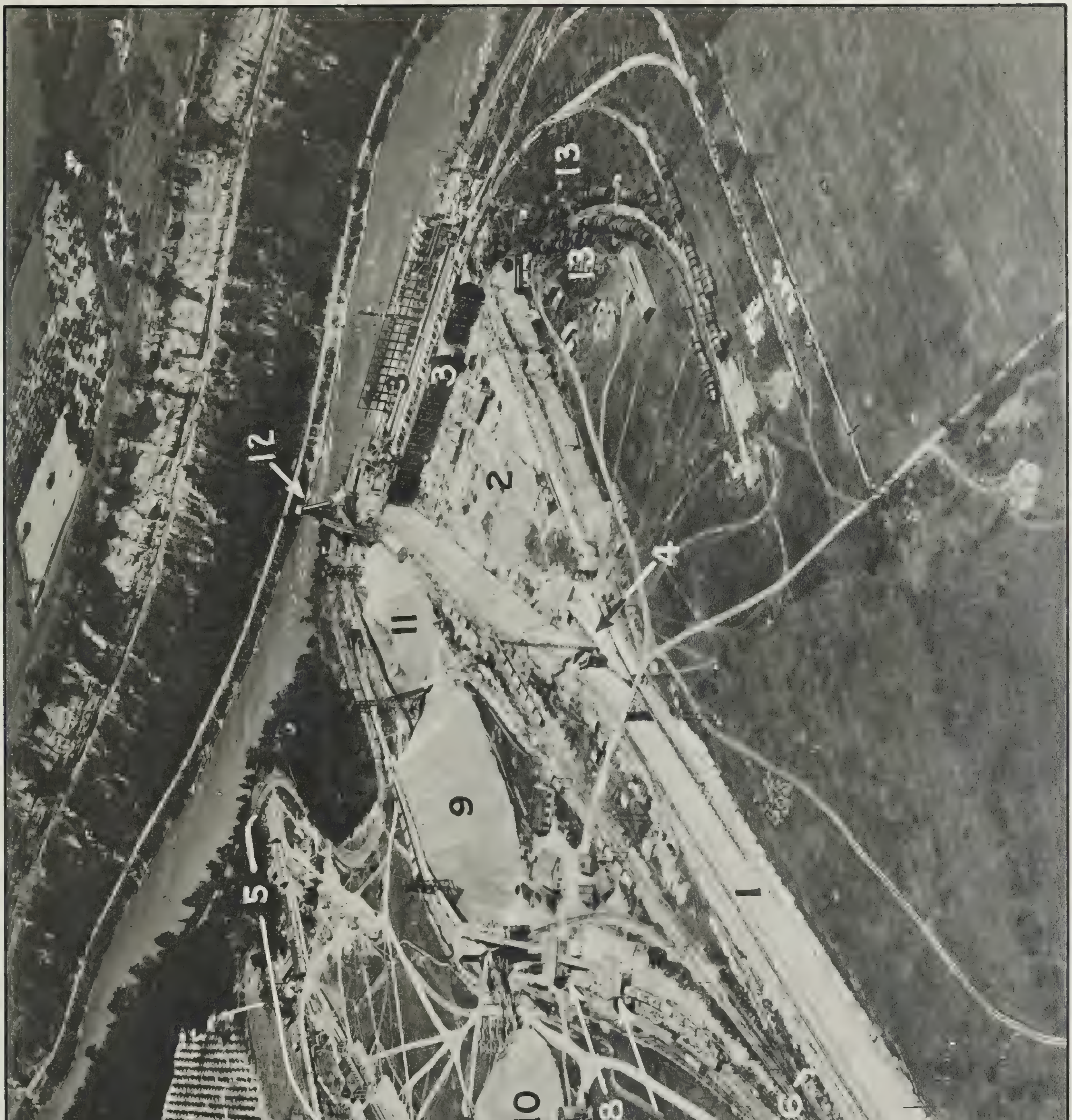
Forebay and end of Canal,

Crusher Plant, Stock Piles and so forth,

looking north-easterly from aeroplane.

Taken September 23rd, 1921.

COPY


12
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1

denotes the lower end of the Canal. The figure 2 is in the centre of the Forebay. The figure 3 marks the Screen House under construction. The diffuser at the mouth of the Forebay is indicated by the figure 4. The camps generally are shown by the figure 5. The figure 6 shows the service tracks on the westerly side of the Canal. The figure 7 points to the first of the crusher plants where the excavated rock is deposited in the hopper directly from the dump cars. The secondary, or 2½-inch crusher plant is indicated by the figure 8. Leading from this may be seen the conveyor which deposits the crushed stone on the stock pile denoted by the figure 9. The figure 10 marks out the stock pile of finer aggregate already referred to. The sand stock pile is shown by the figure 11. The mixing plant for the power house is shown at figure 12, while the figure 13 marks out an area which was used for a general piling ground and stock yard for miscellaneous construction material.

Mixer Plants.

The concrete for the work was made in twenty-one separate plants situated along seven and one-half miles of the development. The concrete mixers were of the standard type, being generally one-yard machines operated singly or in pairs as the circumstances demanded. They were driven by electric motors in all cases.

Construction Methods.

The customary methods of handling the concrete by means of towers, chutes,

hoppers and so forth were used in all the ordinary circumstances. Two of the principal elements of the development, however, or rather two parts of the same element heretofore referred to as the Canal, are worthy of special note and description. One of these is the concrete lining of the Canal on the bottom and sides, and the other the construction of the concrete lining of the whirlpool section of the Canal.

Canal Lining.

The paving of the floor of the Canal and the lining of the sides was designed to be twelve inches in thickness of plain concrete. Accurate field measurements and calculations have been made to determine the actual thickness constructed, and it is considered that the average thickness is something on the order of seventeen inches, the extra thickness being due to the excavation overbreak and to the irregularities of the excavated rock surfaces.

The canal is lined throughout its length in the rock section, a distance of about seven and one-quarter miles.

The sequence of operations in lining the Canal, which required concrete over the whole floor 48 feet in width, and the finish of the walls 33 feet in height, was as follows: first, the paving of a strip of floor 15 feet wide on either side of the canal bottom; second, the construction of the side lining in alternate panels 40 feet in length; third, the filling in of the intermediate panels of the side lining; and fourth, the paving of the centre strip along the bottom of the Canal.

For the transportation of concrete and materials to the mixer plant, a track located on the rock surface at the edge of the excavated section extended along one side of the Canal from end to end of the work. Part of this track was originally laid for the removal of rock excavation, but a high-level cross-over track involving a temporary railway bridge, together with approximately three miles of additional track, was provided expressly for concreting purposes. Pipe lines parallel to the work supplied both water and air under pressure.

The dividing up of the floor into three strips was arranged in order to get widths which could be screeded properly in a longitudinal direction. The centre strip was left until after the lining was placed for two reasons,- to provide space for materials cleaned up from the sides, and to avoid the difficulty that might ensue from the drippings of the lining plant mixers on the finished paving.

The rock forming the floor foundation and the backing of the lining was seamy and water bearing. It is recorded that the pumpage of water entering the Canal through the rock amounted at times to over 15 million gallons per day. To provide drainage for this water, a concrete pipe line was laid below grade along the centre of the canal bottom. Sumps were opened and pumps were installed at intervals of about half a mile. Wherever there was a noticeable flow through the rock the seams were opened up and bulkheaded with planks, and the water was led from behind the bulkhead through a small pipe extending to the floor level.

When the side strips of the floor paving were laid, expansion joints were placed at intervals of 30 feet. These joints were made of two thin boards laid

as an inverted "v", the top of the joint being 2 inches below the floor surface. Channels were thus provided for carrying off the water from the sides to the centre drain. Where the seepage behind the side walls was so diffused as to render its collection impracticable, it was absorbed by the concrete, the mixture of which was adjusted from time to time by duly apportioning the quantities of cement, sand and water.

The floor paving was for the greater part placed by means of travelling paving plants. Later the use of these was abandoned and the work was done by the several lining plants as they progressed, using chutes and concrete buggies. The paving plants received the materials through chutes extending up to cars spotted on the service track.

By the end of 1920 a length of about two miles of the canal prism had been excavated to grade and made ready for concreting. In addition to this, there remained the length of about five and one-half miles of Canal in which the five large shovels were working at separate points. The concrete schedule, therefore required to be arranged so as to complete the whole work immediately after the shovels had finished the excavation. The schedule was carried out so that the concreting was finished eighteen days after the excavation was completed, and the water was admitted into the Canal six days later, that is on December 24th, 1921.

Nine lining plants were erected and used in the work, while later a half-plant was re-assembled from the two plants first dismantled. After an unsuccessful attempt to procure a satisfactory type of plant from specialists in this line of work, the engineers of the Hydro-Electric Power Commission designed

the present units, which were partly manufactured and entirely assembled in their own plant at Niagara Falls.

Each plant was complete in itself consisting of three units,- the form units in front and rear with a mixing unit between the two. Each unit was mounted on special trucks and travelled on tracks laid on the two side strips of the floor already placed. They were moved by means of tackle attached ahead to anchorages set in the rock bottom, the motive power being supplied by the mixing hoists. Each form was suspended from two 75-ton jacks resting on a central structure of steel beams and heavy timbers. These timbers were designed to withstand the added weight of the form panels, the heavy stresses due to moving, and the thrust from a full head of liquid concrete. Each form was kept in place by means of 24 screw jacks operated by hand wheels. The form was made of 3/8-inch steel plate backed up by a frame work of steel beams, and consisted of a base panel 4 feet high, and five movable panels each approximately 6 feet high. The base panel was shaped to form the bevel at the bottom of the side walls. The movable panels could be raised so that spading operations for each 6-foot lift might be carried on by working between the panels. The panels were raised and lowered by means of rods suspended from winches at the top of the structure.

The top of the framework supporting the forms was floored over, and through this floor five openings were provided on either side with a concrete hopper, each of which discharged into a flexible drop chute reaching to the bottom of the forms. A stairway extending from top to bottom of the structure, gave access to platforms at intermediate levels from which the concrete was spaded.

With this plant it required from six to eight hours to fill one set of

the present [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] [illegible].

Each plant was complete in itself, consisting of three units,- the pier units in front and rear with a railway track across the pier. Each unit was mounted on conical trucks and travelled on tracks laid on the two side [illegible] of the floor already placed. They were moved by means of [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] sliding forms. Each form was suspended from ten 10-ton jacks working on a [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible], [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

COPY

[illegible] of 3/8 inch steel plate backed up by a frame work of steel beams, and consisted of a base panel 4 feet high, and two movable panels each approximately 8 feet high. The base panel was clamped to form the level of the bottom of the pier walls. The movable panels could be raised so that concrete operations for each 8-foot lift could be carried on by shifting between two panels. The panels were raised and lowered by means of rods suspended from girders at the top of the structure.

The top of the framework supporting the forms was floored over, and through this floor five openings were provided on either side of a concrete hopper, and by which [illegible] [illegible] into a [illegible].

forms. The maximum output per unit per week was 320 lineal feet of lining.

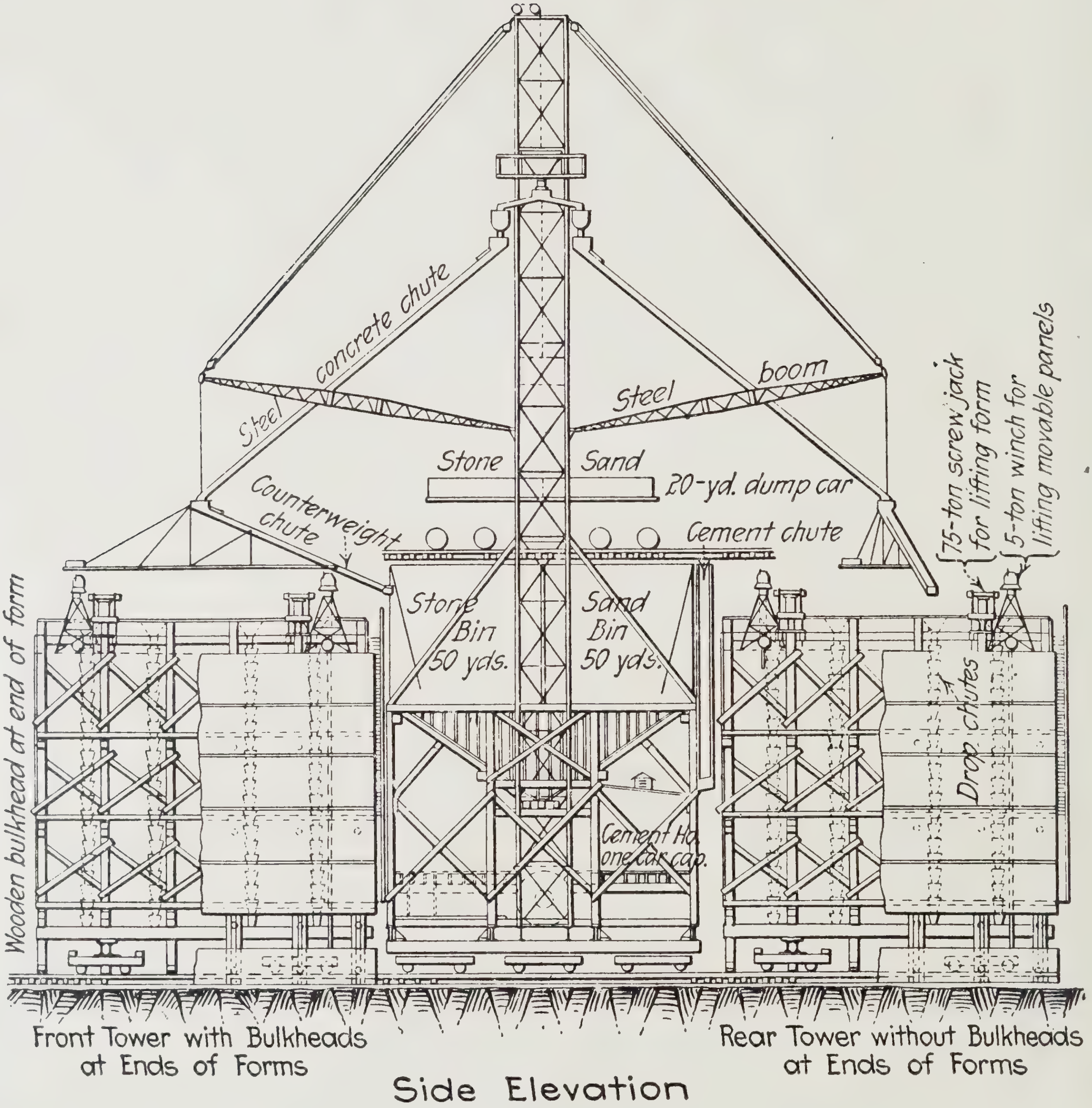
The mixing plant carried a divided bin for aggregate storage with a total capacity of 80 cubic yards, arranged to receive aggregates side-dumped from standard 20-yard cars discharging from the service track which in some cases was over 40 feet higher than the bins. The structure also contained storage room for a carload of cement. The mixer, of one cubic yard capacity, was operated by an electric motor. Concrete was elevated in a one-yard skip by means of an electric hoist and steel tower 95 feet high. At the top of the tower was situated a hopper discharging into two lines of chutes for concreting in the front or the rear forms as desired. The mixing plant also contained apparatus for the application of calcium chloride when used. The total weight of the three units composing a single lining plant was over 500 tons.

At the five bends in the Canal ordinary form work was used. The concrete was delivered already mixed in special hopper cars and deposited directly behind the forms of the adjacent side, and through chutes to the opposite side.

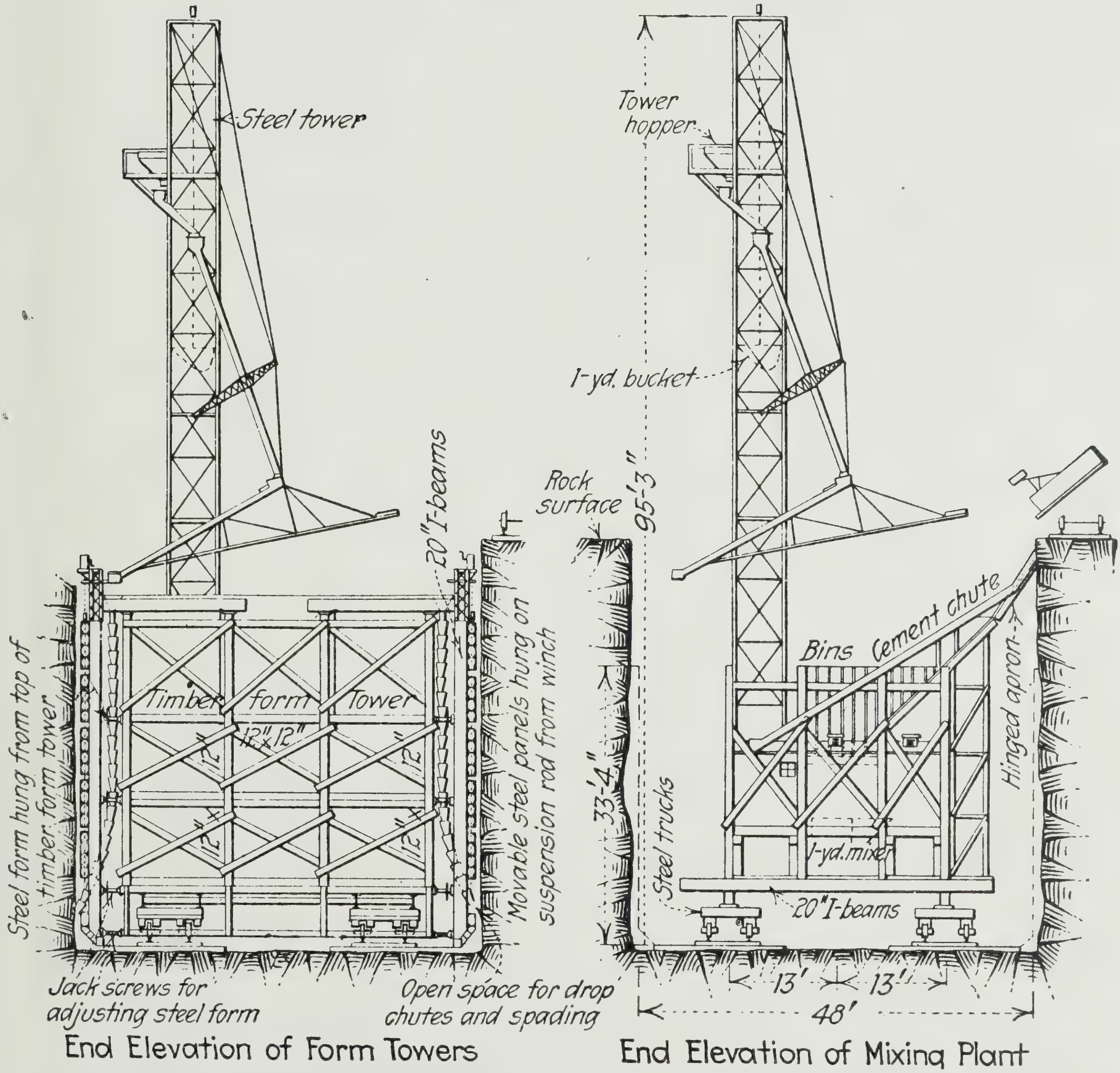
The next succeeding nine pages, being H-19 to H-27, show comprehensively by means of photographs the general design of the lining plants and the various stages of the concrete lining work from the laying of the side strip of floor paving up to the finish of the Canal.

<u>Whirlpool Section Lining.</u>

The trapezoidal of the prism at the whirlpool section, over a mile in



MIXING PLANT AND FORMS FOR PLACING LINING ON POWER



RECTANGULAR SECTION OF QUEENSTON-CHIPPAWA CANAL

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To face page H-20

No. H-2

Photograph showing

Screeds for Side Strips of Canal Paving,

looking along Canal bottom.

Taken October 8th, 1920.

COPY

No. H-3

Photograph showing

Progress in Canal Lining,

looking south from point of starting near Forebay.

Taken January 8th, 1921.

No. H-4

Photograph showing

Canal Paving Plant and Protection of Fresh Concrete,

looking along Canal bottom.

Taken November 4th, 1920.

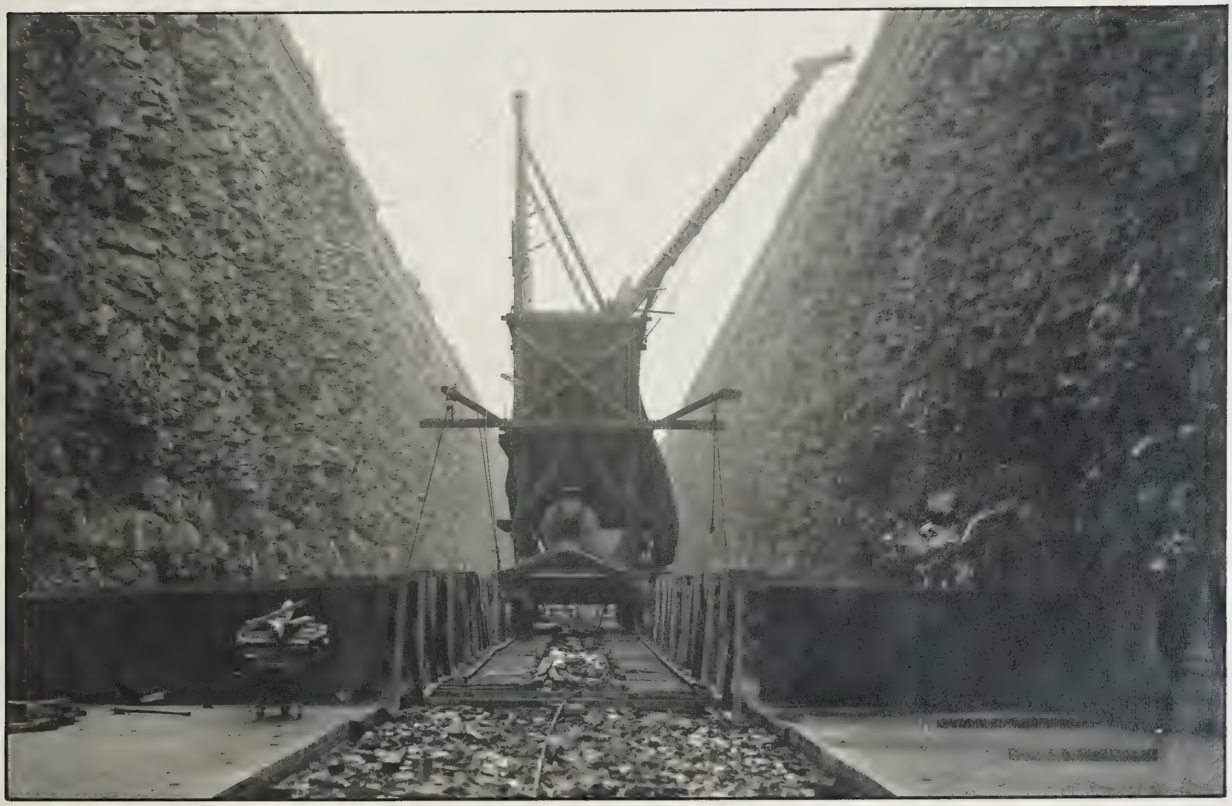
COPY

No. H-5

Photograph showing

Mixer Plant for Canal Lining.

Taken December 2nd, 1920.



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To face page H-22

No. H-6

Photograph showing

Progress of Canal Lining,

looking north from Station 438.

Taken January 8th, 1921.

COPY

No. H-7

Photograph showing

Canal Lining and Retaining Walls,

looking south from M.C.R. - G.T.R. Bridge.

Taken May 18th, 1921.

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To face page E-23

No. H-8

Photograph showing

Finished Canal Lining and Lining Plant in Operation,

looking south from Thorold Road Bridge.

COPY

Taken June 16th, 1921.

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To face page H-24

No. H-9

Photograph showing

Canal Lining Completed from Forebay to Murray's Lane Curve,

looking northerly.

Taken May 19th, 1921.

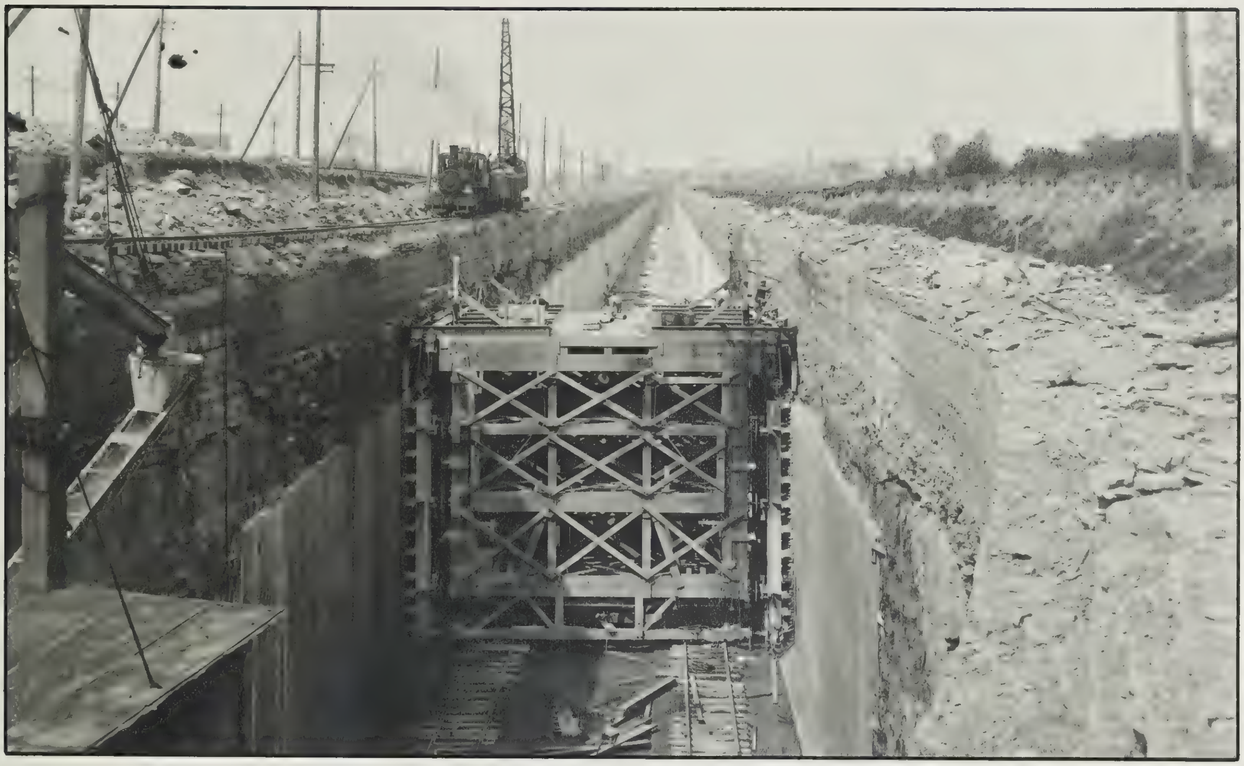
COPY

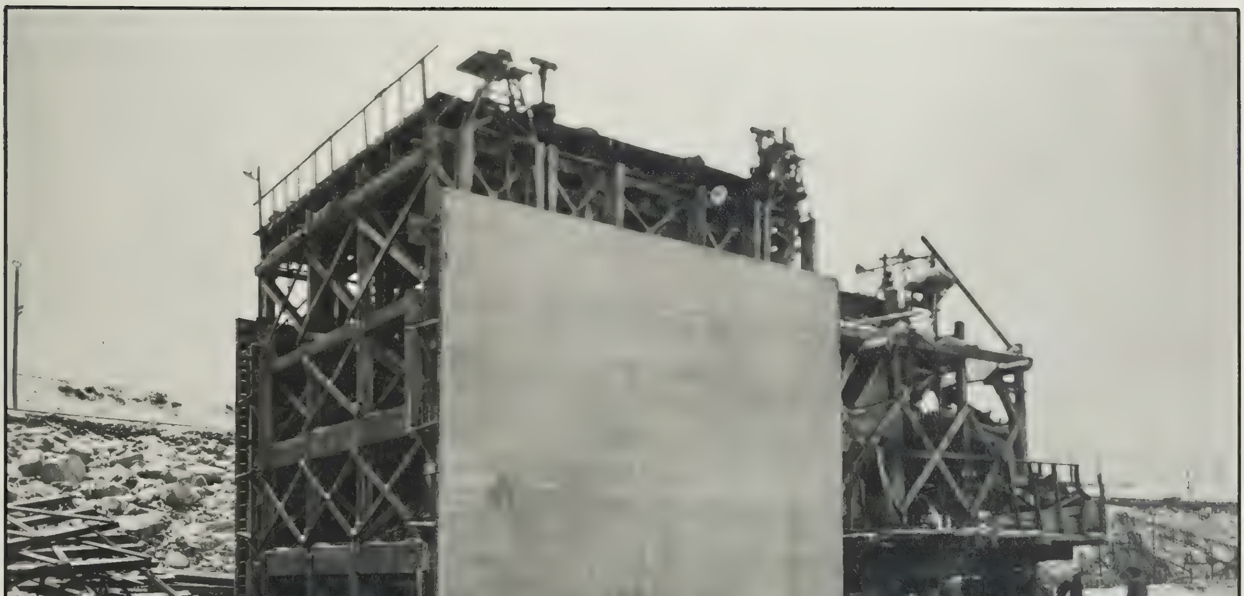
No. H-10

Photograph showing

Front Unit and Mixer of No. 6 Lining Plant.

Taken December 23rd, 1921.





To face page E-25

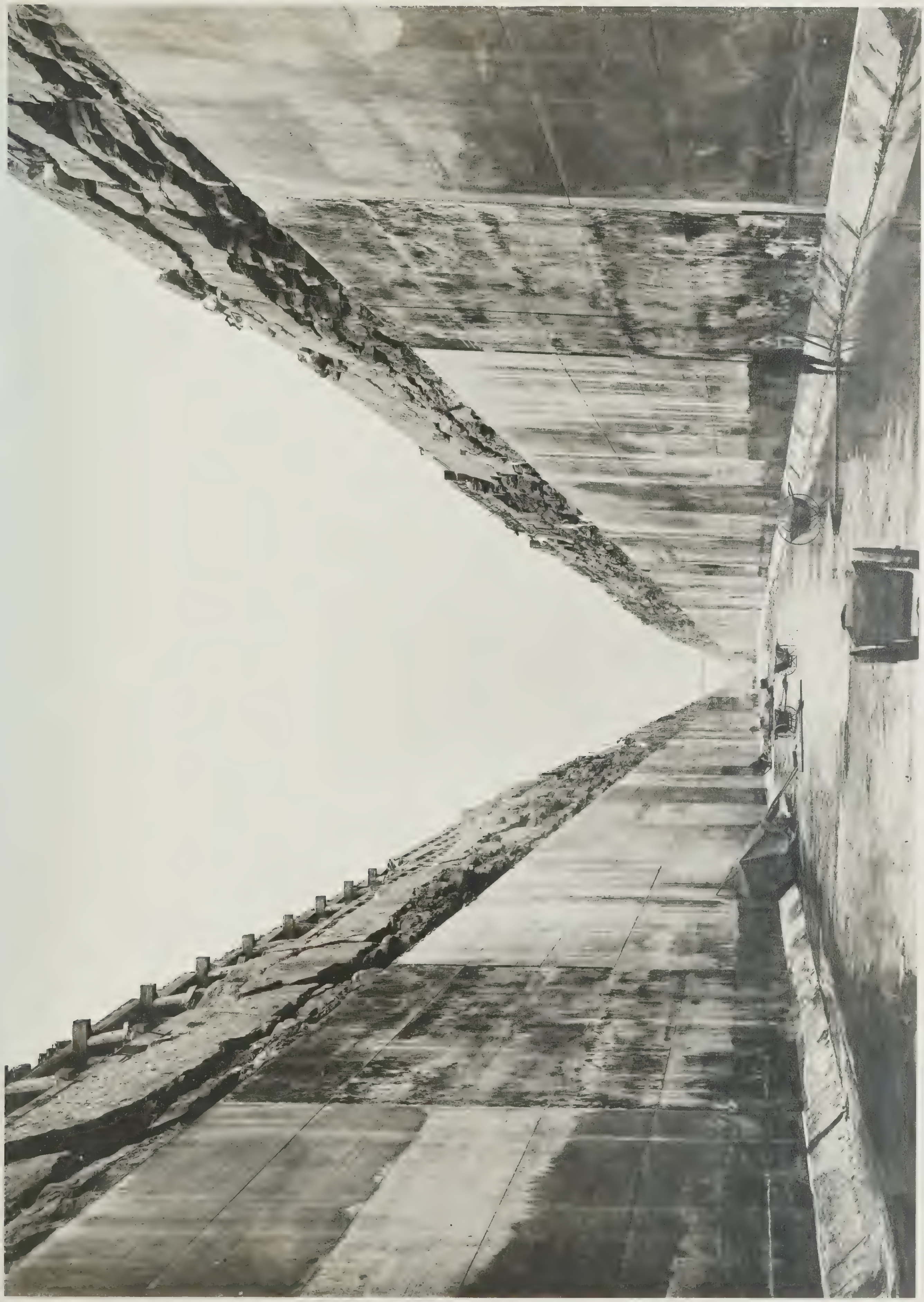
No. E-11

Photograph showing

Finished Canal,

looking north from Station 103+50.

Taken December 22nd, 1921.



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To face page H-26

No. H-12

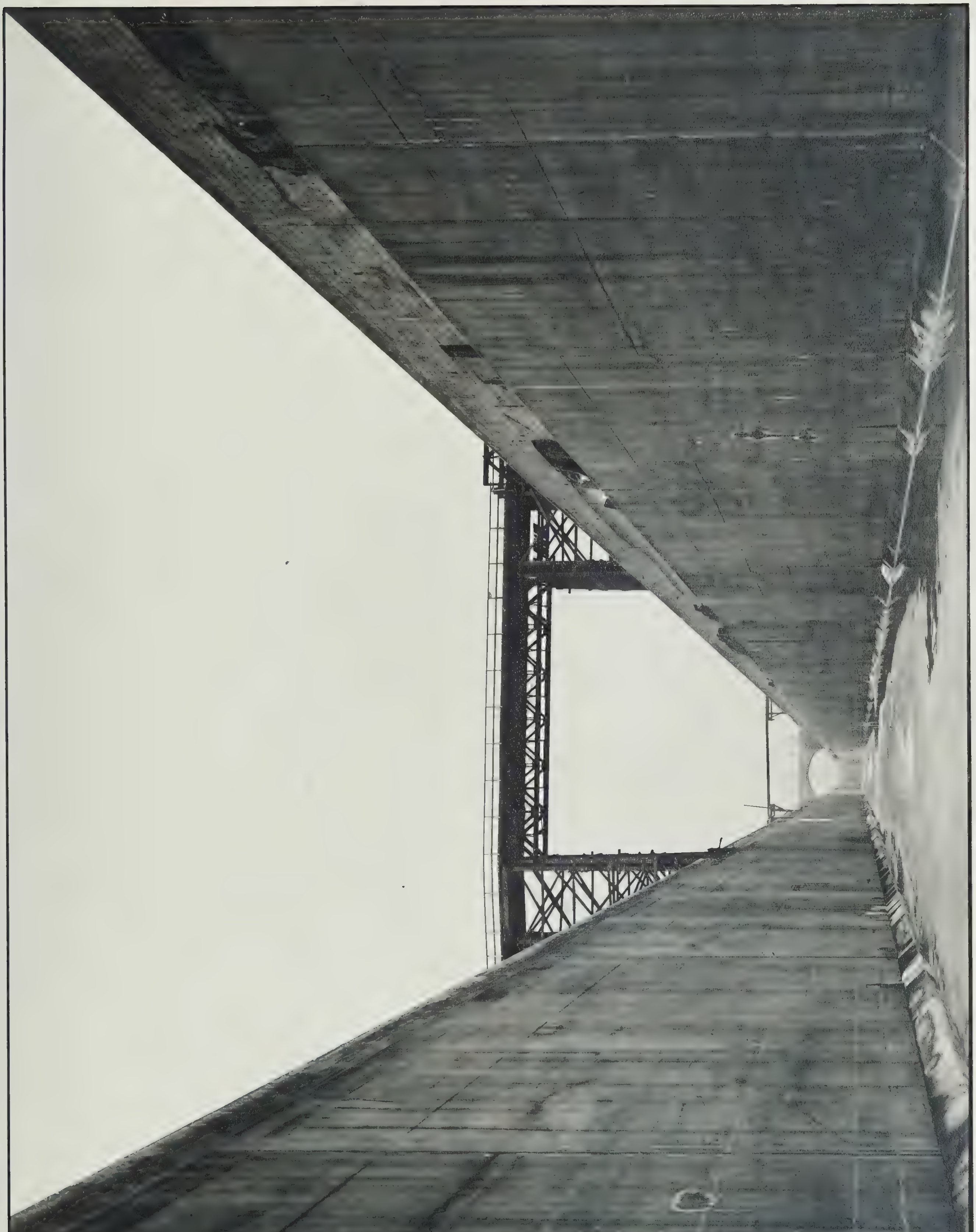
Photograph showing

Finished Canal,

looking under Thorold Road Temporary Bridge.

COPY

Taken December 23rd, 1921.



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To face page H-27

No. H-13

Photograph showing

<u>Finished Canal</u>,

showing M.C.R. - G.T.R. and other bridges.

COPY

Taken December 23rd, 1921.

length, was constructed by a special system. The concrete of the floor and sides was designed to be 12 inches in thickness. A description of the section has already been given in Chapter E, the general description of the development, on page E-25 thereof.

For this work a stationary concreting plant was erected capable of turning out 1,000 cubic yards of concrete per day. This plant consisted essentially of a timber trestle on a 3 per cent. grade for the delivery of aggregates, arranged so that materials could be discharged either from bottom or side-dump cars into the storage bins. The materials were delivered by gravity to the mixers, the cement being unloaded from a track alongside of the plant. The mixers were set sufficiently high above the ground so that the mixed concrete could be discharged into cars.

As it was regarded impracticable to maintain delivery of the raw material throughout the season for the opposite side of the Canal from the plant, it was decided to do all the concrete mixing for the section at one side and convey the concrete across the Canal to the opposite side by means of a chute 330 feet long, for which purpose the material was elevated by a tower 180 feet high. A lower tower was erected on the opposite side, and between the two towers a chute was suspended on a slope of 22 degrees from the horizontal. Two mixers supplied concrete for the work on the side on which the stationary plant was erected, and a separate mixer was provided for the concrete to be delivered for use on the opposite side. Approximately 15,000 cubic yards of mixed concrete was chuted across the Canal from this mixer. The consistency of the concrete was such that delays or stoppages due to clogging the chute

were non-existent.

Specially designed all-steel motor-driven cars, made at the plant, were used for handling the mixed concrete. Steel beams mounted on standard gauge trucks formed a base for four 1½-yard, side-dump concrete car bodies, so placed on the base that two mixers could be discharged into them simultaneously.

The method adopted to form the side slopes, which were of reinforced concrete, was to make narrow strips true to the line of the slopes by means of wooden forms, these concrete strips acting later as guides for the movable forms used for filling the intervening spaces. The movable forms were essentially wide screeds made of steel plate on a structural steel frame. These forms were weighted down by sand bags and drawn up the incline by means of an eight-part-line tackle attached at the top of the slope to a small hand-operated winch. Continuous operation of this winch resulted in a rate of progress up the slope of about eight feet per hour. Concrete reached the forms in galvanized iron chutes laid on the slope, and as the forms progressed the surface of the concrete was given a trowel finish. Six of these forms were in commission, and a daily rate of 4,000 square feet was reached.

The stationary plant erected for this work also supplied concrete for other work along the Canal. The concrete was delivered in good condition from cars, at a distance of over three miles, the mix being specially proportioned for the long hauls.

The ten photographs included in the next succeeding six pages, being H-30 to H-35, show the methods of construction from the commencement of concreting

To face page H-30

No. H-14

Photograph showing

Canal Paving - Whirlpool Section,

looking north from Station 336.

Taken April 7th, 1921.

COPY

No. H-15

Photograph showing

Canal Lining on Slope - Whirlpool Section,

looking north from Station 343.

Taken April 7th, 1921.

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To face page H-31

No. H-16

Photograph showing

Preparation of Slope - Whirlpool Section,

looking north from Station 340.

Taken May 5th, 1921.

COPY

No. H-17

Photograph showing

Concreting Operations on Canal Lining - Whirlpool Section.

Taken May 5th, 1921.

WALTER J. FRANCIS & COMPANY.

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To face page H-32

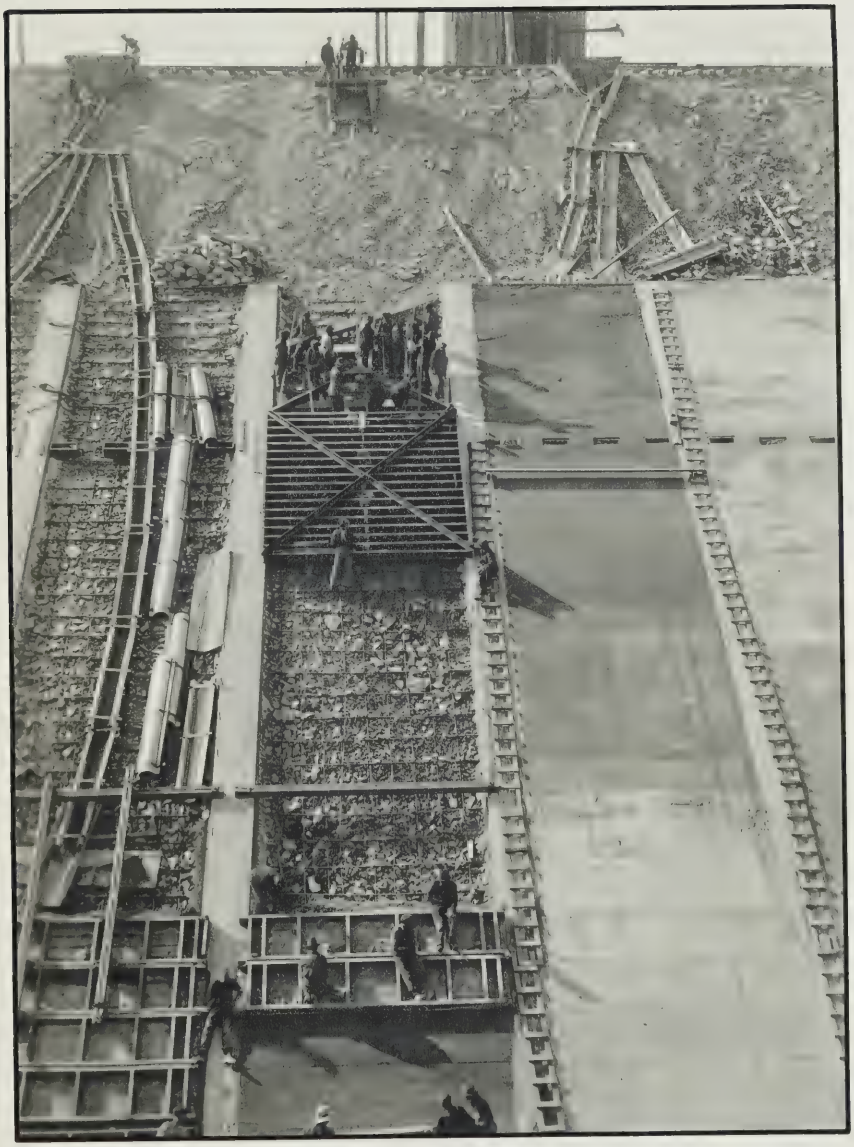
No. H-18

Photograph showing

<u>Details of Concreting Operations on Sloping Side - Whirlpool Section,</u>

COPY

Taken May 5th, 1921.



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To face page H-33

No. H-19

Photograph showing

Finished Concrete Work of Canal Slope - Whirlpool Section.

Taken May 19th, 1921.

COPY

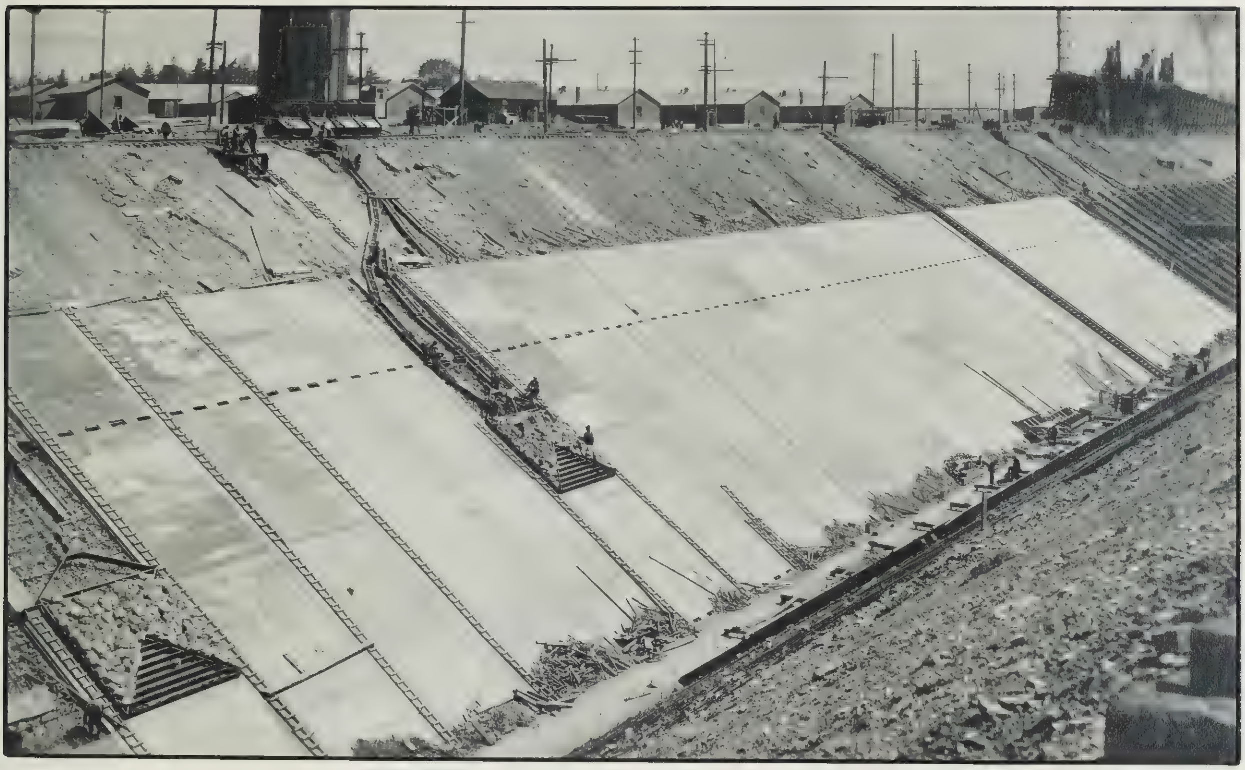
No. H-20

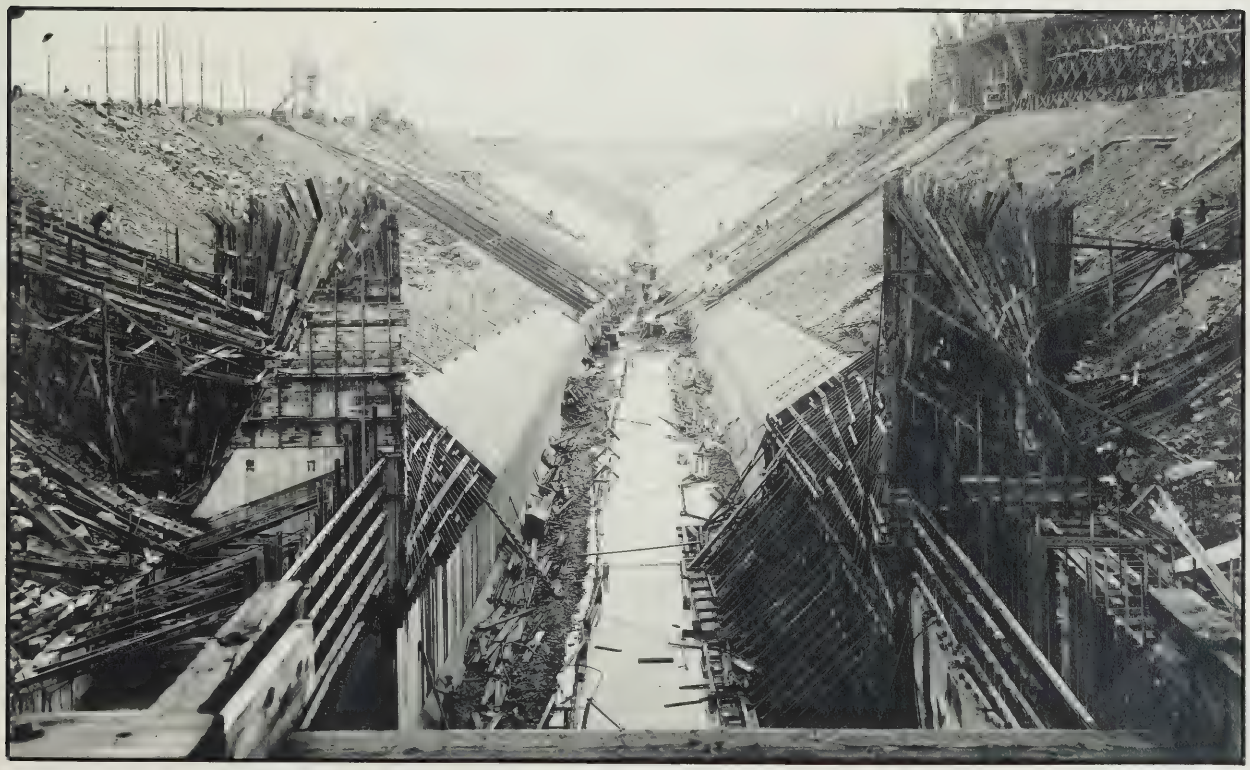
Photograph showing

Transition Construction - Whirlpool Section,

looking through northerly Transition.

Taken June 18th, 1921.





To face page H-34

No. H-21

Photograph showing

Junction of Northerly Transition Section with Canal,

looking north.

Taken July 7th, 1921.

COPY

No. H-22

Photograph showing

Junction of Northerly Transition Section with Canal,

looking north.

Taken July 23rd, 1921.

WALTER J. FRANCIS & COMPANY.

COPY FOR ENCLOSURE TO Mr. J. Allan Ross.

To face page H-35

No. H-23

Photograph showing

General View of Whirlpool Section,

looking northerly.

COPY

Taken December 23rd, 1921.

to the completion of the work on the whirlpool section.

Quantities.

The total quantity of concrete and reinforced concrete in the Queenston-Chippawa Power Development as at March 31st, 1922, is 427,164 cubic yards, exclusive of 190 cubic yards in the counterweight of the Chippawa Highway Bridge. The distribution of the above quantity in the principal elements of the development is as follows:

Canal	304,299	cubic yards
Forebay	6,440	" "
Screen House and related work ...	32,492	" "
Penstocks	9,025	" "
Power House	50,072	" "
Bridges	24,836	" "
Total	427,164	cubic yards

Progress of Concreting.

From November 1st, 1920, to December 17th, 1921, 410,000 cubic yards of concrete were placed, 379,000 cubic yards of this being placed in 1921, of which quantity 332,000 cubic yards were deposited from May to December inclusive, at an average rate of 41,500 cubic yards per month. The record in placing during one day was 3,046 cubic yards with seventeen plants operating, the record week 18,278 cubic yards, and the record month 63,362 cubic yards. The concrete work of the record week, being the week commencing June 20th, 1921, is as follows:

At Power House	1,182	cubic	yards
At Screen House	1,319	"	"
At Forebay	151	"	"
At Forebay (Gunite)	40	"	"
In Division III, Canal Lining			
No. 1 Lining Plant	998	"	"
No. 2 Lining Plant	137	"	"
No. 3 Lining Plant	1,131	"	"
No. 4 Lining Plant	1,306	"	"
No. 5 Lining Plant	1,866	"	"
No. 6 Lining Plant	2,170	"	"
Curve Lining Plant	336	"	"
No. 1 Paving Plant	137	"	"
No. 2 Paving Plant	219	"	"
No. 4 Paving Plant	172	"	"
No. 5 Paving Plant	966	"	"
By Montrose Stationary Plant A	1,381	"	"
By Whirlpool Stationary Plant	4,737	"	"
Total	18,278	cubic	yards

COPY

Construction Procedure.

As already set forth more particularly in Chapter G, which deals with construction procedure, all of the concrete work on the Queenston-Chippawa Power Development was completed by the engineers of the Hydro-Electric Power Commission under the force account system of procedure, with the exception of about 190 cubic yards of concrete in the counterweight of the Chippawa Highway Bridge done by the contractors for the bridge superstructure as part of their contract therefor. For this latter amount the engineers of the Hydro-Electric Power Commission exercised regular engineering supervision, the contractors being responsible for plant and labour in the usual way. The greater part of the quantity 427,164 cubic yards was done directly by the special construction force under the immediate direction and control of the Chief Hydraulic Engineer.

In the superstructure of the Power House and in certain parts of the Screen House and of bridge superstructures assistance was rendered by the Electrical Department and by the Railway Department, respectively, the Chief Hydraulic Engineer being in immediate charge of the necessary co-ordination, all as set forth in Chapter F which describes in detail the organization for the work.

Walter J. Francis

Consulting Engineer.

Toronto, January 3, 1923.

COPY